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WO 92/08037 A1 US 5033545 A US 4790376 A
US 4744730 A US 4297084 A US 3887008 A

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(54) Recovery of liquids from underground reservoirs

(57) A recovery method and apparatus for lifting liquid from an underground reservoir to a wellhead via a twin nested pipe arrangement extending from the reservoir to the wellhead. The inner pipe (12) conveys the liquid from the reservoir upwardly to the wellhead and the annular space between the pipes serves to convey a gaseous driving pressure medium e.g. hydrocarbon gas to operate a specially designed jet pump (20, 30) located within the inner pipe. The jet pump receives a supply of the gaseous driving pressure medium from the surrounding outer pipe through an inlet (24), the pressure differential thereby established across the jet pump assisting the uplifing of the liquid through pipe (12) under reservoir pressure and reduces the hydrostatic load of the upwardly moving column of liquid. After carrying out this pumping action, the gas is exhausted into the upwardly flowing column of liquid in the pipe (12) and moves upwardly with it in the manner of a gas lift. Instead of the single tapered nozzle gas outlet (24b), a series of separate jet outlets arranged in a circle may be used.

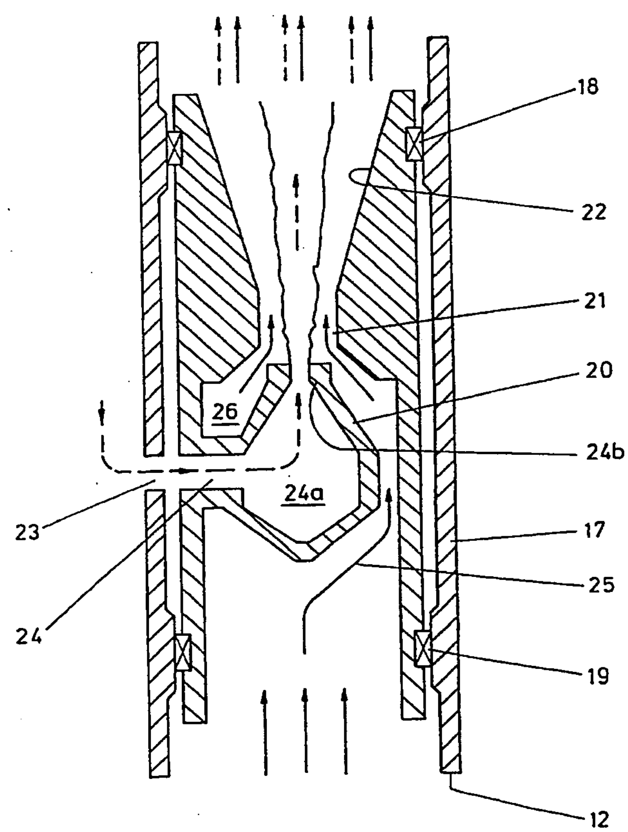

FIG. 2

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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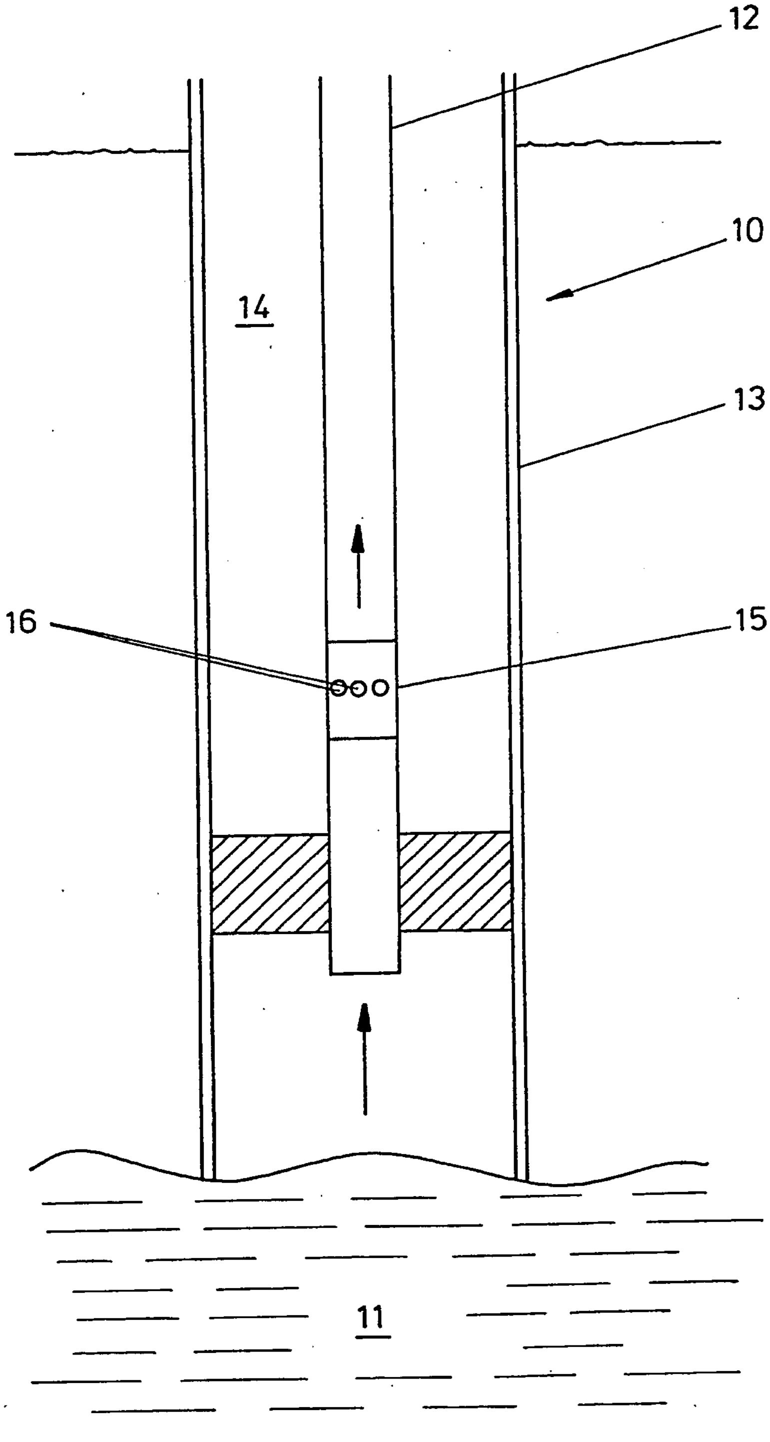

FIG. 1

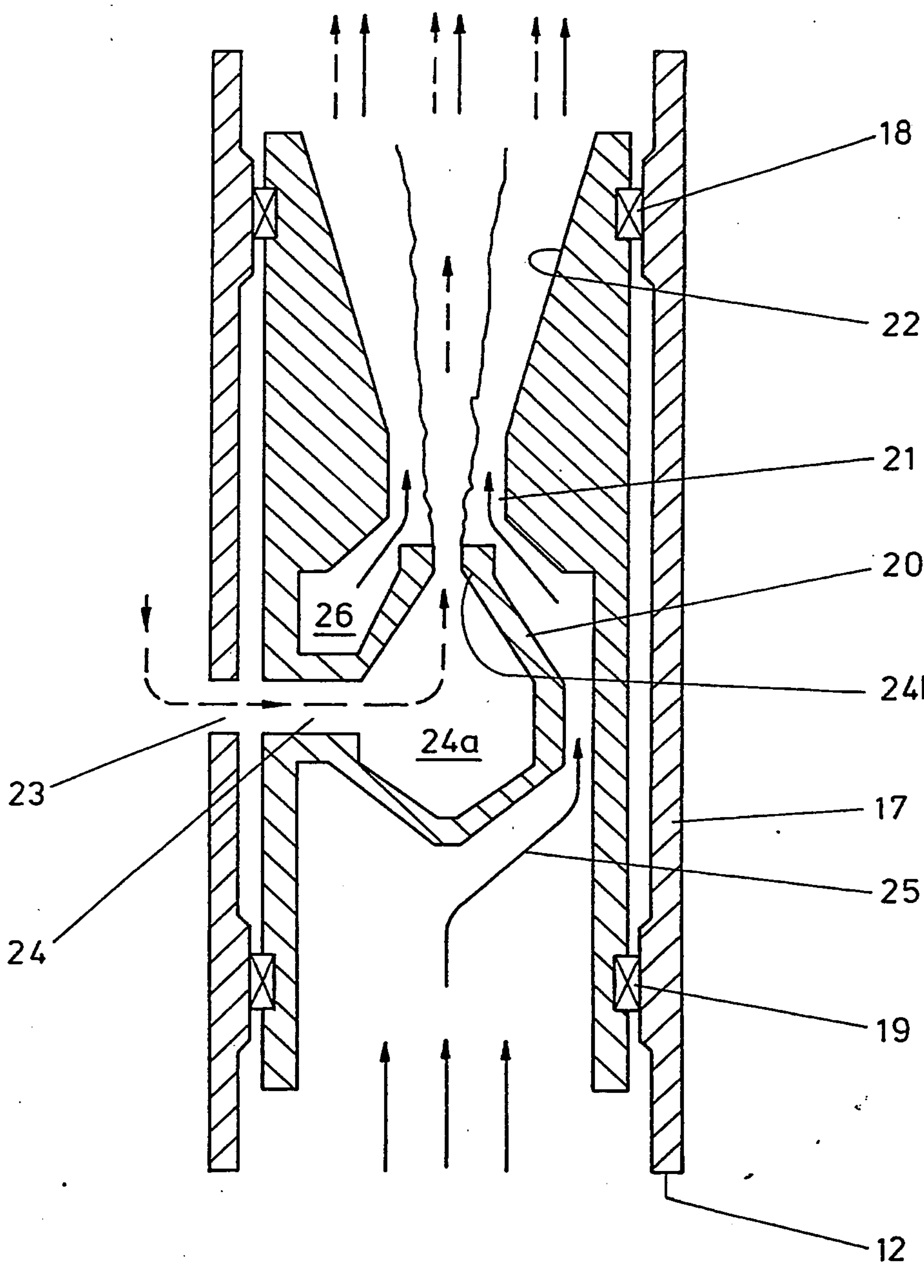

FIG. 2

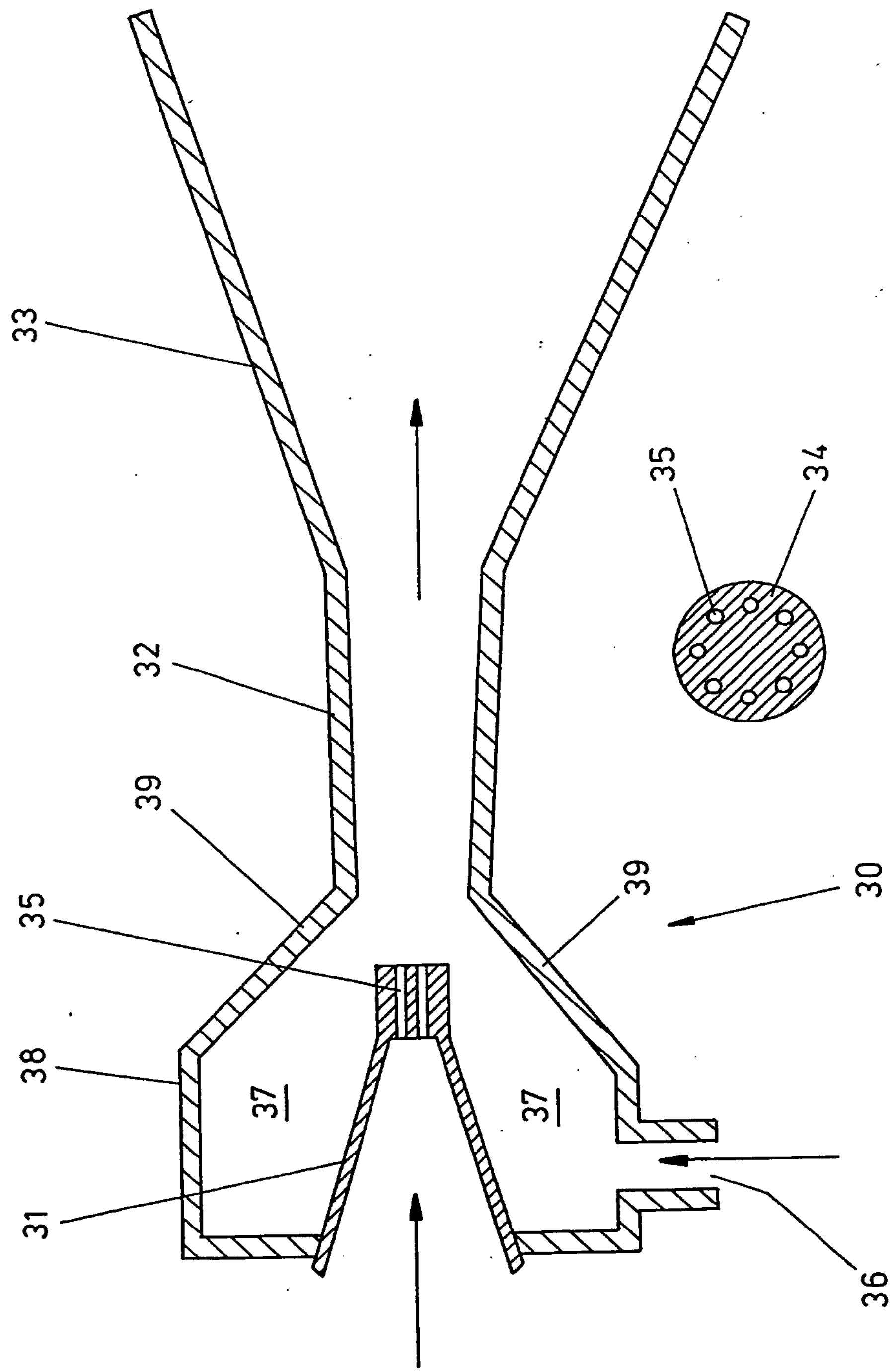

FIG. 3

RECOVERY OF LIQUIDS FROM UNDERGROUND RESERVOIRS

This invention is concerned generally with the recovery of liquids from underground reservoirs. such as oil reservoirs below the seabed. and provides a novel method and apparatus for use in a liquid recovery system.

The invention has been developed primarily. though not exclusively. in connection with the recovery of residual oil from reservoirs in which naturally available delivery pressure e.g. natural gas in the reservoir chamber. has partly been used-up. or reduced to such a level that assistance is required to "lift" the oil. The residual oil in such reservoirs. as well as oil at low pressure in so far untapped reservoirs. represents a significant natural resource which is worth recovering. and particularly as the more readily recoverable sources of oil become used-up.

There are a number of different methods employed in order to recover or "lift" low pressure oil from underground reservoirs. and which include hydraulic pumping. so-called "gas lift". electric submersible pumps (ESP) and rod pumping.

Hydraulic pumps are subdivided into jet pumps. positive displacement (piston) type pumps. and centrifugal pumps driven by turbines.

In all existing methods. the purpose of the assistance to the uplifting of the reservoir oil is to reduce the hydrostatic load of the column of oil passing up an oil production pipe. thereby allowing reservoir pressure to be more effective.

The present invention seeks to use a combination of gas lift and a pumping action in order to provide enhanced flow rates of oil from a well. and with improved efficiency.

In this specification. references to "underground reservoirs" of course will also include reservoirs below the seabed.

In the extraction of oil from underground reservoirs, it is usual to employ a concentric twin pipe arrangement, which comprises a central oil production pipe or conduit by which the oil is conveyed to a surface wellhead from the reservoir, and an outer pipe or conduit which lines the borehole. An annular space is therefore defined between the outer surface of the central oil production pipe and the inner surface of the liner. In a "gas lift" application, a gas inlet is arranged in the wall of the oil production pipe at a significant depth below the wellhead, and takes the form of a tubular component which forms an integral part of the pipe. Pressure gas is then introduced into the annular space, and enters the oil production pipe via the tubular component, and then rises within the pipe and thereby promotes upward movement of oil from the reservoir up the production pipe to the wellhead.

This upward movement of the oil is caused by the upward movement of the gas, which reduces the hydrostatic head within the pipe, and for increases in gas pressure up to a critical level of gas pressure, the greater the pressure of gas supply, the higher will be the flow rate of oil.

However, as the gas pressure increases, the frictional gas pressure drop within the production pipe also increases, and eventually a position is reached in which the oil flow rate will no longer increase, but will in fact decrease with further increase in gas supply pressure. Furthermore, the gas used in the gas lift process has to be separated from the oil at the wellhead, and increased volumes of gas supplied in order to enhance the oil flow rate can present serious handling problems in separation of the gas, and consequently adversely affect the oil throughput.

Hydraulic pumping is also used to "lift" oil from underground reservoirs, and employs a hydraulic pump which is located within the oil production pipe, and again at a

significant distance below the wellhead. Any suitable driving liquid pressure medium (which in practice is often water) is used to operate the pump, and this is supplied to the annular space between the liner and the oil production pipe, and from which it passes through the wall of the production pipe to enter the pump and cause it to operate.

The operation of the pump causes it to act on the oil in the pipe and pump the oil up from the reservoir to the wellhead. The type of pump typically employed is arranged to receive the driving liquid and to mix the driving liquid with the driven liquid (oil) which then pass upwardly together in mixed form to the wellhead, and therefore these two liquids then have to be separated before further handling or treatment of the oil takes place.

The pumping effect achieved by this arrangement is obtained by energy transfer within the pump between the driving liquid (water) and the driven liquid (oil), which causes the pressure of the driving liquid to decrease with consequent reduction in the intake pressure at the oil inlet to the pump, whereby the oil is pumped-up from the reservoir via the pump and then upwardly in mixed form to the wellhead. In this way, the use of a hydraulic pump can achieve enhanced flow rate of oil from the reservoir to the wellhead.

However, since this pumping method relies upon commingling of the driving and the driven liquids, there is the disadvantage of having to provide some suitable separation means at the wellhead, or downstream of the wellhead, in order to separate the driving liquid from the oil.

The present invention therefore seeks to provide an improved recovery system for lifting liquid from an underground reservoir to a wellhead, and which employs advantageous aspects of "gas lift" and pumping techniques in a combined form.

According to a first aspect of the invention there is

provided a recovery system for lifting liquid from an underground reservoir to a wellhead via a twin pipe arrangement extending from the reservoir to the wellhead and comprising one pipe arranged within another pipe, and in which:

a first of the pipes serves to convey the liquid from the reservoir upwardly to the wellhead and a second of the pipes serves to convey a gaseous driving pressure medium to operate the system:

the first pipe has a gas-operated pump which is arranged to receive a supply of gaseous driving pressure medium from the second pipe which operates the pump and thereby causes the pump to apply an upward pumping action to the liquid; and,

the arrangement of the pump is also such that the gaseous driving medium used to operate the pump is caused to exhaust into the first pipe and thereby move upwardly with the liquid in the manner of a gas lift.

According to a second aspect of the invention there is provided a recovery apparatus for lifting liquid from an underground reservoir to a wellhead, said apparatus comprising:

a twin pipe arrangement to extend from the reservoir to the wellhead, and comprising one pipe arranged within another pipe, and in which:

a first of the pipes is arranged to convey the liquid from the reservoir upwardly to the wellhead and a second of the pipes is arranged to convey a gaseous driving pressure medium to operate the apparatus:

the first pipe incorporates a gas-operated pump which is arranged to receive a supply of gaseous driving pressure medium from the second pipe to operate the pump and thereby cause the pump to apply an upward pumping action to the liquid; and,

the arrangement of the pump is such that the gaseous driving pressure medium used to operate the pump can be

caused to exhaust into the first pipe and thereby move upwardly with the liquid in the manner of a gas lift.

The invention therefore provides for recovery of liquid from an underground reservoir in a combined manner which utilises the advantage of a novel means of applying a pumping action on the liquid in conjunction with a gas lift effect.

According to a third aspect of the invention there is provided a method of recovering, or assisting the recovery of liquid from an underground reservoir of liquid by lifting the liquid from the reservoir to a wellhead via a twin pipe arrangement extending from the reservoir to the wellhead, said arrangement comprising one pipe arranged within another pipe, and in which:

a first of the pipes conveys liquid from the reservoir upwardly to the wellhead under reservoir pressure and a second of the pipes conveys a gaseous driving pressure medium:

the first pipe incorporates a gas-operated pump which receives a supply of gaseous driving pressure medium from the second pipe via a gas pressure inlet and which operates the pump to apply an upward pumping action to the liquid; and,

the pump exhausts the gaseous driving pressure medium into the first pipe, after it has caused the pump to apply the upward pumping action to the liquid, so that the exhausted gas can move upwardly with the liquid in the manner of a "gas lift".

Preferably, the gas-operated pump comprises a jet pump which is arranged to receive the supply of gaseous driving pressure medium and to discharge the gas as a throttled jet into the upwardly moving column of liquid in the first pipe in such a way as to create a pressure differential which reduces the hydrostatic load of the column and thereby allows reservoir pressure to be more effective in driving the liquid from the reservoir and up the first pipe to the

wellhead.

In a particularly preferred form, the jet pump has an inlet chamber which receives the pumped supply of gas from the second pipe, a tapered nozzle outlet from the chamber, a throat arranged to receive the gas jet produced by the nozzle, a by-pass chamber in communication with the throat and with the first pipe to receive liquid from the first pipe from below the jet pump and on which liquid a pumping action is applied by the gas jet issuing from the nozzle, and a diffuser which receives a combined output of gas and pumped liquid from the throat.

The design parameters of the nozzle, by-pass chamber, throat, and diffuser will be determined by suitable testing to provide optimum efficiency in utilisation of the energy of the pumped supply of gas which is transferred to the uplifted liquid i.e. to create a substantial pressure differential, and the exhausted gas i.e. after transfer of pumping energy to the uplifted flow of liquid, will then provide further assistance in uplift of the liquid by operating as a "gas lift" during travel upwardly of the first pipe from the jet pump to the wellhead.

Usually, said first pipe will be an inner pipe arranged within an outer liner which forms said second pipe, and preferably the inner pipe is located centrally within the outer liner. The gaseous driving pressure medium therefore will be supplied to the annular space defined between the outer surface of the internal pipe and the inner surface of the liner, and any suitable gas inlet will be arranged in the wall of the inner pipe in order to communicate the gas in the annular space with a gas pressure inlet to the pump.

However, this arrangement is not essential to the invention, and a reverse arrangement may be provided, in which the gaseous driving pressure medium is supplied to an inner pipe and the upward pumping of the recovered liquid takes place via the annular space between the inner pipe

and the outer liner.

The invention is particularly applicable to the recovery of oil from reservoirs below the seabed, and the gaseous driving pressure medium will normally be hydrocarbon gas derived from a surface separator. However, it should be understood that the invention is applicable generally to the lifting of liquids from underground reservoirs.

In the particularly preferred and practical embodiment for achieving dual function utilisation of a gaseous pressure supply, in which the pumping action is obtained by means of the jet pump arrangement having the nozzle, throat and diffuser sections, these sections are introduced into an oil production pipe in such a way as to allow the upwardly moving flow of oil to by-pass the jet pump, and then to be exposed to a dual action lifting effect.

The gaseous pressure supply is therefore admitted through a housing aperture to the nozzle section of the jet pump from which it can issue as a high speed jet which is delivered sequentially to the throat section and then to the diffuser section. The by-passed flow of oil is also conveyed to the throat section and then to the diffuser section, and during movement through these sections, energy is transferred from the high speed gas jet as it slows down during movement along the throat and diffuser sections, which applies a pumping action on the slower moving oil flow. The oil flow takes place in an annular space defined between the jet and the walls of the throat and diffuser sections. This pumping action increases the production rate from the reservoir, and the commingled driving fluid (gas) and reservoir fluids then flow upwardly to the well head.

Although pumping energy has been derived from the high speed gas jet, there is still residual energy in the gas flow as it becomes exhausted from the throat and diffuser sections, and bubbles of gas can then flow upwardly within

the production pipe to provide a "gas lift" which further assists the upward flow of reservoir oil.

Examples of liquid recovery method and apparatus according to the invention will now be described in detail with reference to the accompanying drawing, in which:

Figure 1 is a schematic illustration of a recovery system and apparatus for lifting oil from an underground reservoir to which the invention may be applied:

Figure 2 is a detailed sectional view of one practical embodiment of dual function gas-operated jet pumping arrangement according to the invention: and,

Figure 3 is a sectional view, similar to Figure 2, of a further embodiment of gas-operated jet pumping arrangement according to the invention.

Referring first to Figure 1 of the drawings, this shows, by way of example only, a recovery system and apparatus for use in lifting oil from an underground oil reservoir. The oil in the reservoir will be assumed to have insufficient reservoir pressure available in order to provide a required upward oil flow rate from the reservoir to a wellhead (not shown) via a twin pipe arrangement within the bore hole. The system which will now be described is therefore intended to enhance the oil flow rate from the reservoir to the wellhead. This example will be described in relation to the upward lifting of oil from a reservoir, but it should be understood that the invention will be applicable generally to the lifting of liquids from underground reservoirs. The recovery system is designated generally by reference 10 and is intended to lift oil from an underground reservoir 11 to a wellhead (not shown) via a twin pipe arrangement which comprises one pipe arranged within another pipe, and extending upwardly from the reservoir 11 to the wellhead.

The twin pipe arrangement comprises an inner oil production pipe 12 which is arranged centrally within an outer pipe 13 which comprises a usual liner of a bore hole.

Thus, in the illustrated arrangement, the inner pipe 12 comprises the first pipe of the twin pipe arrangement which serves to convey the oil from the reservoir 11 upwardly to the wellhead under the action of reservoir pressure, whereas the outer liner pipe 13 serves to convey a gaseous driving pressure medium to improve the rate of uplift of oil, such driving medium being supplied to the annular space defined between the outer surface of the inner pipe 12 and the inner surface of the outer liner pipe 13.

The pipe 12 has a gas-operated pump (not shown) which is arranged to receive a supply of gaseous driving pressure medium from the annular space 14, and which is able to operate the pump (not shown) and thereby cause the pump to apply an upward pumping action to the oil. The gas from the space 14 passes to the pump via a suitable gas inlet arranged in the wall of the pipe 12, which in the schematic arrangement shown comprises a tubular component 15 having a circumferentially spaced set of inlet apertures 16. The tubular component 15 forms a component part of the pipe 12.

The pump (not shown) which is arranged within the pipe 12 therefore applies an upward pumping action to the oil by creation of a substantial pressure differential, upon the supply of the gaseous pressure medium to operate the pump, but there is a further arrangement whereby the gaseous driving medium which is used to operate the pump is caused to exhaust into the pipe 12, and thereby to move upwardly with the oil in the manner of a gas lift. Accordingly, the gaseous pressure medium supplied to the system has a dual function, in that it provides the power source to drive a pump which exerts a pumping action on the oil, but when it is vented from the pump it then functions in the manner of a gas lift, as the gas bubbles pass upwardly through the pipe 12 alongside the oil which is moving upwardly under dual action, namely pumping by the pump and also by reason of the "gas lift" effect of the upwardly moving gas stream.

The arrangement as shown in the drawing comprises an inner oil production pipe and an outer liner which is pressurised with the gaseous pressure medium. However, it should be understood that the system could readily be reversed, whereby the gaseous pressure supply is conveyed to an inner pipe, and then moves outwardly to operate the pump which exerts a dual action upward pumping movement to oil which moves upwardly through the annular space defined between the outer liner and the inner pipe.

The preferred gas employed in the dual function gas-operated lifting system of the invention comprises the hydrocarbon gas which is readily available at the usual surface separator.

Figure 1 shows, in schematic form only, the manner by which a supply of gaseous pressure medium may be utilised in a dual function (a) to provide input power to a pump and (b) after exhausting from powering the pump to mingle with the upwardly pumped flow of oil to augment the flow by the "gas lift" effect.

However, by way of example only, Figure 2 shows one practical embodiment by which this may be achieved.

Referring therefore now to Figure 2, this shows the introduction of a jet pipe arrangement into the oil production pipe 12 of Figure 1, and shows one practical embodiment for tubular component 15 shown schematically in Figure 1. An outer housing 17 of the jet pump arrangement forms an integral part of the production pipe 12 of Figure 1, and the jet pump arrangement is sealed within the outer housing 17 between upper and lower seals 18 and 19, and comprises a nozzle section 20, a throat section 21 and a diffuser section 22.

A supply of gaseous pressure medium, preferably comprising hydrocarbon gas at substantial pressure e.g. in the range 2000 to 4000 psi, is conveyed to an inlet chamber 24a of the nozzle section 20 via an aperture 23 in the outer housing 17, and an inlet 24 to the nozzle section 20,

and then a high speed gas jet is formed in tapered nozzle outlet 24b which issues into the throat section 21 and then subsequently into the diffuser section 22. As the jet travels along the throat section 21 and diffuser section 22, its velocity decreases. However, the column of oil moving upwardly under reservoir pressure in production pipe 12 is guided in by-pass manner around the nozzle section 20, as shown by arrow 25, and into an annular by-pass chamber 26 surrounding the outlet of nozzle section 20. The oil (reservoir fluid) is relatively slower moving than the high speed gas jet, and energy is therefore transferred from the gas jet to the slower moving reservoir fluid which flows in the annular space created between the jet and the walls of the throat and diffuser sections 21, 22.

The passage of the gas jet along the throat 21 and into the diffuser 22 also creates a pressure differential which is applied to the upwardly moving column of oil to assist its upward movement.

In particular, the passage of the gas jet along throat 21 and diffuser 22 causes a reduction of pressure in the column of oil downstream of the nozzle section 20 relative to the pressure prevailing upstream of the nozzle section i.e. below the nozzle section, which reduces the hydrostatic load of the column extending up the production pipe to the wellhead, and thereby allows the reservoir (driving) pressure to be more effective.

Figure 2 is a schematic illustration only, and the design and dimensions of the nozzle section 20, throat 21 and diffuser 22 will be determined experimentally to provide the most advantageous utilisation of the energy of the gaseous pressure supply, to suit any particular oil production facility.

For example only, surprisingly it has been found by tests to be advantageous to make the length of the throat section 21 to be short, or even to virtually eliminate the throat section, so that the throttled gas jet passes almost

immediately into the diffuser section.

As a result, the production rate from the reservoir is increased, and the commingled driving fluid (gas) and reservoir fluids then flow upwardly to the well head. However, although pumping energy has been derived from the high speed gas jet, there still remains residual energy within the gas, which can move upwardly in the manner of a "gas lift" with the oil flow, to further enhance the lifting effect derived from the gaseous pressure supply to the system.

As indicated above, the design parameters of the nozzle section 20, chamber 26, throat section 21 and diffuser section 22 will be selected according to tests carried out on the particular gas and liquid media involved, so as to optimise the efficiency of transfer of pumping energy from the gas jet to the liquid, while allowing the exhausted gas to function as a "gas lift" to assist the uplift of liquid e.g. crude oil to the wellhead.

Initial test data indicate that, as compared with an existing oil production facility using "gas lift" by a high pressure natural gas supply, the use of the same supply passing through a suitably designed gas jet pump can result in increased oil production rates of at least 5%.

Test description

Preliminary testing of the concept has been carried out on a land based test facility, in advance of field testing on an existing oil production platform, and has shown favourable indications, using fresh water in place of oil and nitrogen gas in place of hydrocarbon gas.

A jet pump design generally similar in principle to that shown schematically in Figure 2 was evaluated, with fresh water being pumped along a pipe incorporating the jet pump at rates between 2000 to 4000 bbl / day using a triplex pump. Nitrogen gas was injected into the jet pump as a power fluid, at rates between 1 to 6 mmscf / day, and pressures between 2000 to 5000 psi. A variable choke was

used to control the pump discharge pressure, allowing the pressure rise generated across the jet pump to be monitored.

Preliminary results

The jet pump was found to be successful in developing a positive head, which showed that the gas / liquid mixing provided sufficient momentum to overcome the frictional losses through the pump. One indication of trial pump performance comprised a pressure rise from 1800 to 1940 psig when pumping 2000 bbl / day of water with 3 mmscf / day of nitrogen. The nitrogen supply pressure was 4000 psig.

Field application

Based upon a mathematical model developed using the test results, the performance of a gas-powered jet pump in downhole service has been predicted. A well producing 3900 barrels per day with 2.7 mmscf / day of 0.85 SG gas lift has been considered. With gas-powered jet pumping at 4000 psi nozzle pressure, a production rate of 4100 barrels per day should be attainable, which is an approximate increase in rate of output of about 5%.

This improvement is commercially significant, in that the high pressure driving gas fluid supply is already available to provide a gas lift effect, and the incorporation of the specially designed jet pump into the production pipe will provide this improvement in output rate without need for any appreciable increase in operating costs and extra equipment. It is envisaged that further increase in the rate of output beyond the 5% value already achieved will be obtainable, subject to further refinement in the design parameters of the components of the jet pump.

A further embodiment of gas-driven jet pump for use in the invention is shown schematically in Figure 3 of the drawings, and which is designated generally by reference 30. Jet pump 30 will be incorporated as a separate tubular component into an oil production line, in similar manner to

that shown in Figure 2. and comprises a nozzle section 31, a throat section 32 and a diffuser section 33. As can be seen from Figure 3. nozzle section 31 defines a convergent passage for incoming high pressure gas; and which is then directed through a nozzle 34 having a circular array of circumferentially spaced jet outlets 35.

The upwardly flowing column of liquid e.g. oil passes into the jet pump 30 by way of inlet 36 and then into annular chamber 37 which surrounds the nozzle section 31. and which comprises a suction chamber. The cylindrical wall 38 of suction chamber 37 then merges into a converging wall 39 which defines a contraction chamber. and wall 39 then merges into a slightly diverging wall defining the mixing throat section 32. Throat section 32 then merges into the diverging wall of diffuser section 33.

The design features of the various component sections of jet pump 30. and including particularly the annular array of jet outlets 35. are intended to provide further enhancement in application of pressure differential to the upwardly flowing column of liquid which draws the liquid via inlet 36 into the jet pump 30. In addition to the pumping effect applied to the upwardly flowing column of liquid, the gas jets issuing from nozzle section 31 then form gas bubbles in the diffuser section 33 which give additional "lift" to the upwardly moving column of oil by way of "gas lift" effect.

Figure 3 shows generally axially extending jet outlets 35. but it is envisaged that further advantage may be achievable if the jet outlets 35 are at least slightly convergent e.g. to follow the convergence of the wall 39 of the contraction chamber.

Figure 3 is a schematic illustration only. and again, as with the previously described schematic illustrations, the design shape and dimensions may be varied, as found best by experimental testing to suit particular requirements of any oil production facility. the type of

oil being uplifted and the gaseous pressure driving medium employed, which usually will be hydrocarbon gas.

CLAIMS

1. A recovery system for lifting liquid from an underground reservoir (11) to a wellhead via a twin pipe arrangement (12, 13) extending from the reservoir (11) to the wellhead and comprising one pipe (12) arranged within another pipe (13), and in which:

a first of the pipes (12) serves to convey the liquid from the reservoir (11) upwardly to the wellhead, and a second of the pipes (13) serves to convey a gaseous driving pressure medium to operate the system;

the first pipe (12) has a gas-operated pump (20, 30) which is arranged to receive a supply of gaseous driving pressure medium (16, 23, 36) from the second pipe (13) which operates the pump and thereby causes the pump to apply an upward pumping action to the liquid; and,

the arrangement of the pump (20, 30) is also such that the gaseous driving pressure medium used to operate the pump is caused to exhaust into the first pipe (12) and thereby move upwardly with the liquid in the manner of a gas lift.

2. A recovery apparatus (10) for lifting liquid from an underground reservoir (11) to a wellhead, said apparatus comprising:

a twin pipe arrangement (12, 13) to extend from the reservoir (11) to the wellhead, and comprising one pipe (12) arranged within another pipe (13), and in which:

a first of the pipes (12) is arranged to convey the liquid from the reservoir (11) upwardly to the wellhead and a second of the pipes (13) is arranged to convey a gaseous driving pressure medium to operate the apparatus;

the first pipe (12) incorporates a gas-operated pump (20, 30) which is arranged to receive a supply of gaseous driving pressure medium (16, 23, 36) from the second pipe (13) to operate the pump (20, 30) and thereby cause the pump to apply an upward pumping action to the liquid; and,

the arrangement of the pump (20. 30) is such that the gaseous driving pressure medium used to operate the pump can be caused to exhaust into the first pipe (12) and thereby move upwardly with the liquid in the manner of a gas lift.

3. A method of recovering. or assisting the recovery of liquid from an underground reservoir (11) of liquid by lifting the liquid from the reservoir to a wellhead via a twin pipe arrangement (12. 13) extending from the reservoir to the wellhead. said arrangement comprising one pipe (12) arranged within another pipe (13). and in which:

a first of the pipes (12) conveys liquid from the reservoir (11) upwardly to the wellhead under reservoir pressure and a second of the pipes (13) conveys a gaseous driving pressure medium:

the first pipe (12) incorporates a gas-operated pump (20. 30) which receives a supply of gaseous driving pressure medium from the second pipe (13) via a gas pressure inlet (16. 23. 36) and which operates the pump (20. 30) to apply an upward pumping action to the liquid: and.

the pump (20. 30) exhausts the gaseous driving pressure medium into the first pipe (12) after it has caused the pump to apply the upward pumping action to the liquid. so that the exhausted gas can move upwardly with the liquid in the manner of a gas lift.

4. Apparatus according to Claim 2. in which the gas-operated pump comprises a jet pump (20. 30) which is arranged to receive the supply of gaseous driving pressure medium and to discharge the gas as a throttled jet into the upwardly moving column of liquid in the first pipe (12) in such a way as to create a pressure differential which reduces the hydrostatic load of the column and thereby allows reservoir pressure to be more effective in driving the liquid from the reservoir (11) and up the first pipe (12) to the wellhead.

5. Apparatus according to Claim 4, in which the jet pump (20) has an inlet chamber (24a) which receives the pumped supply of gas from the second pipe (13), a tapererd nozzle outlet (24b) from the chamber (24a), a throat (21) arranged to receive the gas jet produced by the nozzle (20), a by-pass chamber (26) in communication with the throat (21) and with the first pipe (12) via passage (25) to receive liquid from the first pipe (12) from below the jet pump (20) and on which liquid a pumping action is applied by the gas jet issuing from the nozzle (20), and a diffuser (22) which receives a combined output of gas and pumped liquid from the throat (21).

6. Apparatus according to Claim 4 or 5, in which nozzle section (20), throat (21) and diffuser (22) comprise a unit mounted in an outer housing (17) which is adapted to form a component part of a central oil production pipe (12) arranged within an outer liner (13).

7. Apparatus according to Claim 2, in which the jet pump (30) comprises a nozzle section (31) arranged within an inlet chamber (37) to which the liquid can be admitted via a liquid inlet (36), a throat section (32) adjoining the nozzle section 31, and a diffuser section (33).

8. Apparatus according to Claim 7, in which the wall (38) defining inlet chamber (37) merges into the wall of throat section (32) via a wall (39) which defines a contraction chamber.

9. Apparatus according to Claim 7 or 8, in which the throat section (32) is slightly divergent in the direction of gas / liquid flow, and then merges into diffuser section (33).

10. Apparatus according to any one of Claims 7 to 9, in which the nozzle section (31) comprises a series of separate jet outlets (35).

11. Apparatus according to Claim 10, in which the jet outlets (35) are circumferentially spaced from each other in a circular array.

12. A method according to Claim 3, in which hydrocarbon gas is used to operate the gas-operated pump (20, 30) to assist the uplifting of oil from a reservoir (11).

13. A method according to Claim 12, in which the hydrocarbon gas is supplied at a pressure in the range 2000 to 5000 psi, and the design parameters of the jet pump (20, 30) are such as to create a pressure differential across the jet pump of at least 150 psi to assist the uplifting of the moving column of oil in oil production pipe (12), prior to exhaution of the gas into the production pipe (12).

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
GB 9123379.1

Relevant Technical fields

(i) UK Cl (Edition L) F1E

(ii) Int Cl (Edition 5) F04F 5/24
E21B 43/12

Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner

B W DENTON

Date of Search

18 DECEMBER 1992

Documents considered relevant following a search in respect of claims 1-13

Category (see over)	Identity of document and relevant passages		Relevant to claim(s)
X Y	WO 92/08037 A1	(PECO MACHINE SHOP) whole document	1-13
X Y	US 5033545	(SUDOL) whole document; see particularly lines 55 column 2 - line 40 column 4	1-8
X Y	US 4790376	(WEEKS) whole document; but especially note column 1 lines 60-63	1-8,12
Y	US 4744730	(ROEDER) see Figures 5-11 and line 26 column 5 - line 3 column 7	9-11
Y	US 4297084	(WAYT)	10,11
X Y	US 3887008	(CANFIELD) see especially Figures 2, 3 and table page 5	1-8,12,13

Category	Identity of document and relevant passages	Relevant to claim(s.

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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